



Accelerator Simulation in the Computing Division

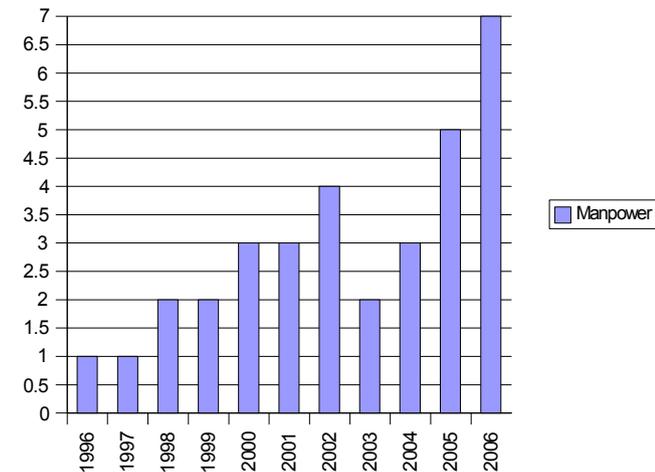
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Accelerator Simulation in CD

- A mature activity (~10 year involvement)
 - Forward looking (R&D oriented)
 - '96-'02 ionization cooling μ -collider/ ν -factory
 - '01-... multi-particle dynamics (Run-II, ILC)
 - '05-... single-particle optics (ILC,...)
 - '06-... electromagnetics (ILC,...)
 - Emphasis on
 - Infrastructure development
 - applications/beam studies

AMR
Department

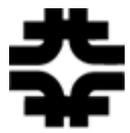




Accelerator Simulation in CD

Our activities add to the accelerator physics modelling expertise at Fermilab; they are well matched to **CD specific skills** and to **existing CD infrastructure**

- Experience developing "user oriented" software
- Combining theoretical, experimental, and computational background
- Great wealth of experience in running efficiently parallel clusters (IQCD group)



Approach

- Work closely with AD operations and theory experts
- Seek collaboration with experts outside Fermilab
- Maximize **utilization of non-core funding** opportunities:

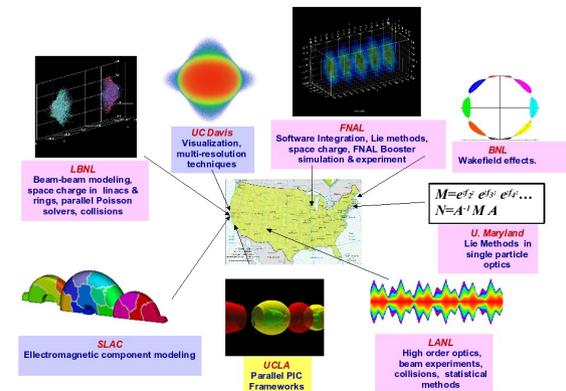
Since '01 members of a **multi-institutional collaboration** funded by SciDAC to develop & apply parallel **community codes** for **design and operation optimization**.

Funds received June '05-June '06: \$150k

1 FNAL resident collaborator **funded by a phase-II SBIR** (TechX)

SciDAC-2 proposal submitted (FNAL lead institution)

Phase-I SBIR (starts Oct '06) awarded (Tech-X)





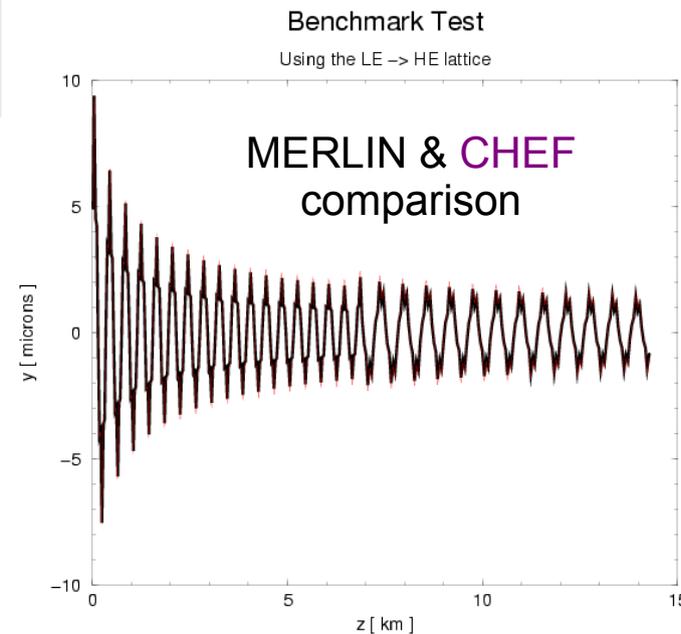
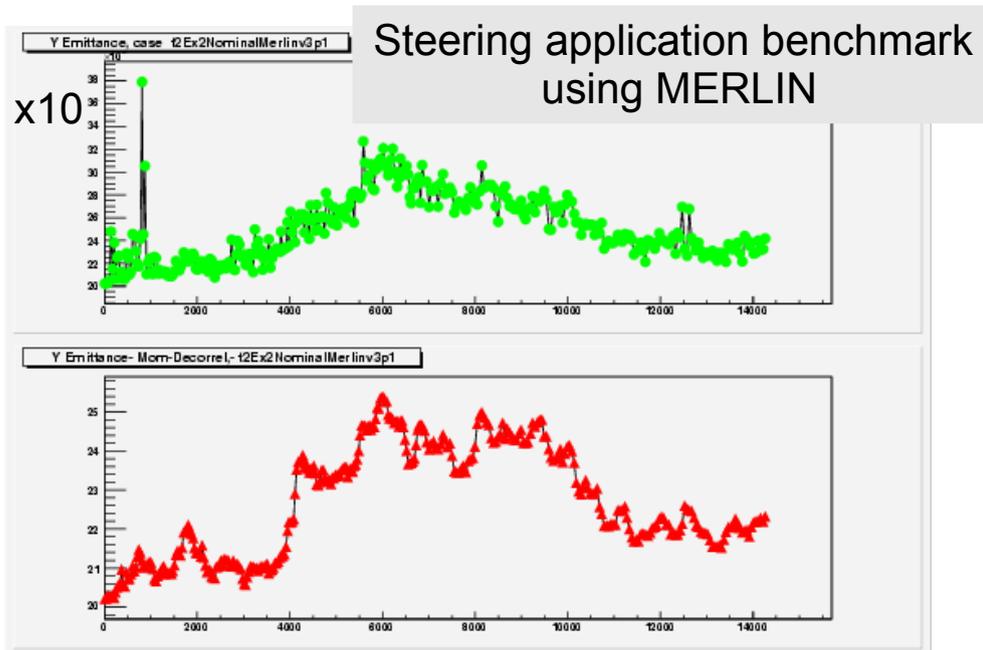
Focus of FY06 activities

- Utilize mature 3D space-charge capabilities
 - study **Booster losses & ILC Damping Ring**
- Validate beam-beam 3D code & incorporate realistic **Tevatron** lattice and multi-bunch model
- Start gaining experience in e-cloud modeling
 - **Main Injector upgrades, ILC Damping Ring**
- Develop expertise in ILC Low Emittance Transport design
 - **Learn/utilize existing tools, adapt our tools**
- Release Synergia2, our fully configurable parallel framework, aiming for **multi-physics** capabilities
- Evaluate potential involvement in **Electromagnetics modeling**



ILC Main Linac

- Ported ILC software (MatLIAR, MERLIN)
 - began studies of emittance dilution & steering techniques
- Extended our **CHEF*** libraries to handle electrons and ILC specific physics requirements (cavities, wakefields)



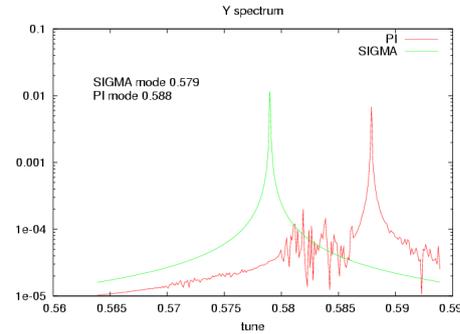
Activity
level
@1 FTE

*Collaborative Hierarchical Expandable Framework: arbitrary order Lie maps (single particle optics); MAD parser; automatic differentiation, numerical integration.

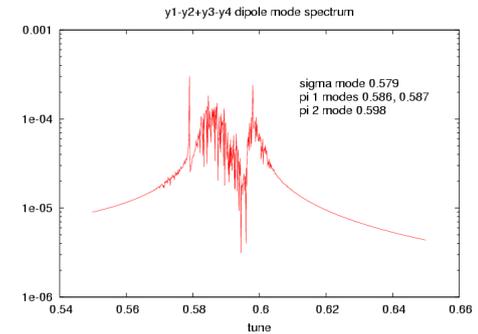


Beam-beam

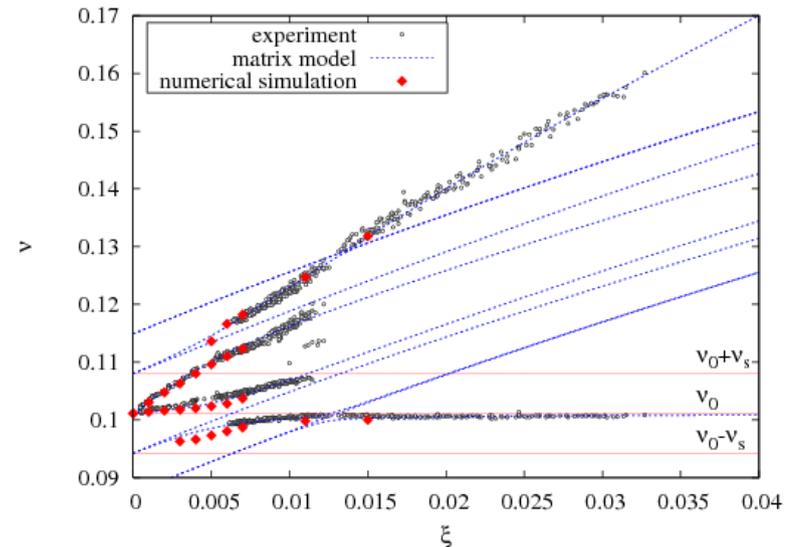
- 3D, multi-bunch, multi-IP capabilities
 - Utilize BeamBeam3D (SciDAC), adapt for Tev requirements
 - Realistic lattice, multi-bunch/IP scheme
 - Code validation (VEPP-II, theory)
- Work closely with AD



2-bunch coherent



4-bunch coherent

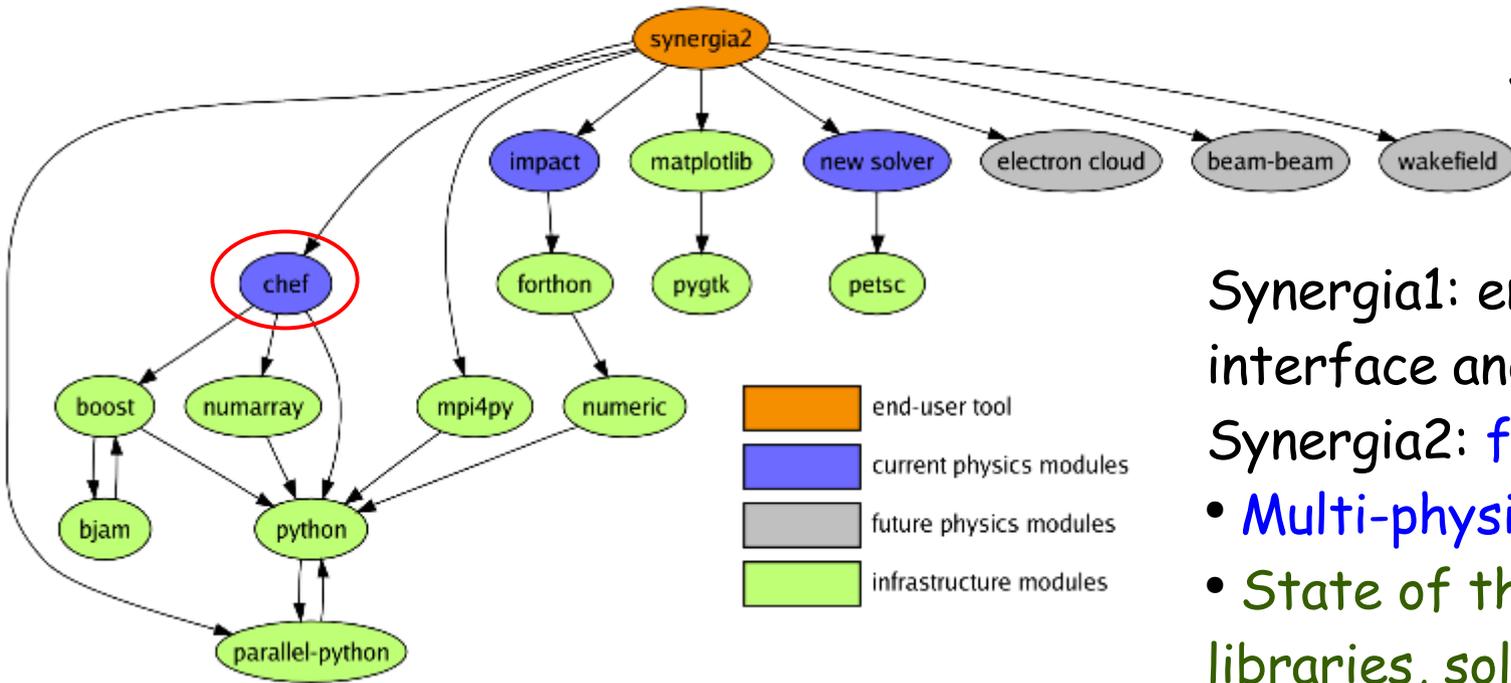


Beam-beam code validation comparing with VEPP-II data

Activity ~1 FTE



Fermilab SciDAC product: Synergia

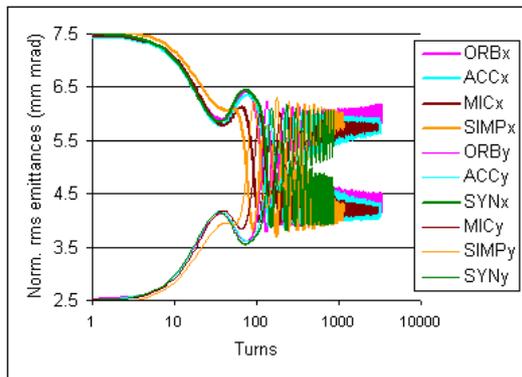


Synergia2 released in '06

Synergia1: emphasis on user interface and space-charge

Synergia2: flexible & efficient

- Multi-physics & realistic models
- State of the art numerical libraries, solvers, physics modules

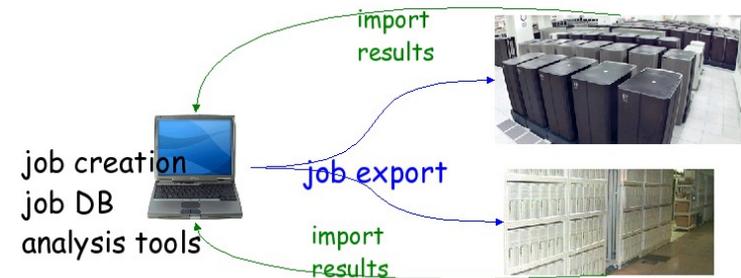


Synergia1: mature code

(JCP '06)

Participated in international "space-charge benchmark"

effort lead by I.Hofmann (GSI) (PAC'05)

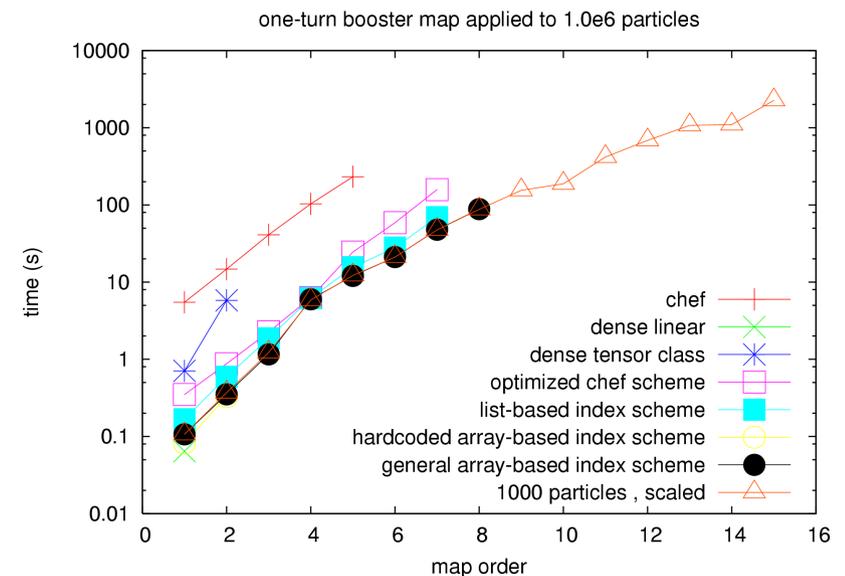
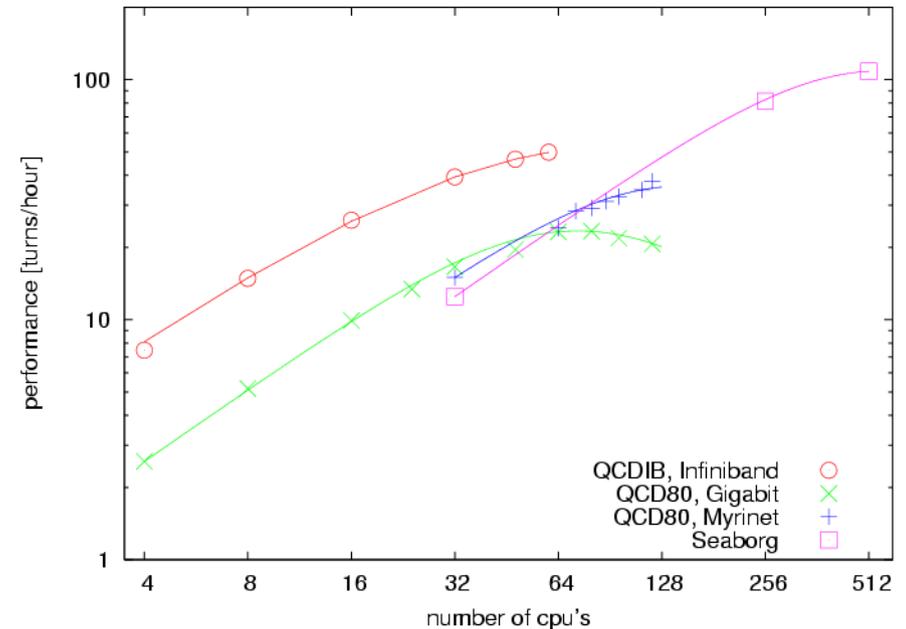


Activity at 1.3 FTE



Synergia performance

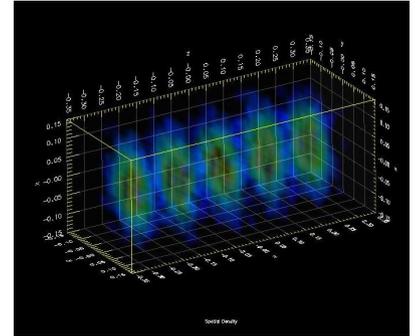
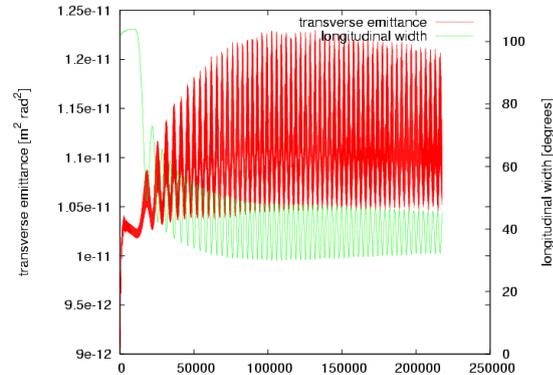
- Utilized NERSC SP3 and Linux clusters
 - Recycle IQCD hardware
- Studies of parallel performance
 - Case-by-case optimization
- Optimization of particle tracking



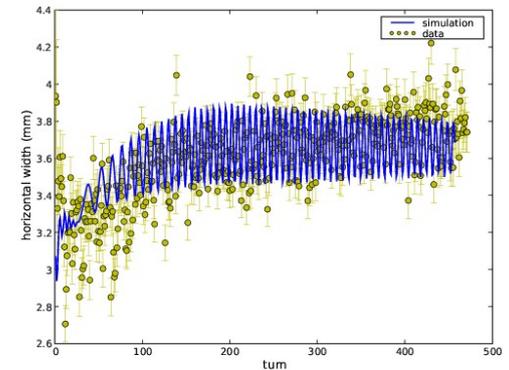


Booster activity highlights

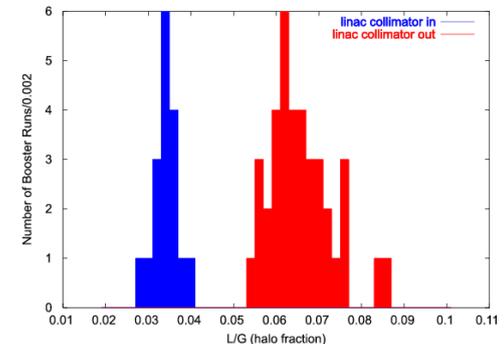
- Synergia to study halo creation & emittance dilution
 - Beam studies, turn-by-turn profiles (IPM, our calibration PRSTAB '03)
 - 3D model enables study of phase space correlations
 - Important to fully understand dynamic aperture



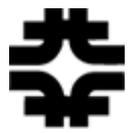
3D Booster simulation including injection, rf ramping, etc. Comparison with experimental data



New technique for halo characterization using beam shape (submitted to PRSTAB)



Activity @0.5 FTE, plus grad-student

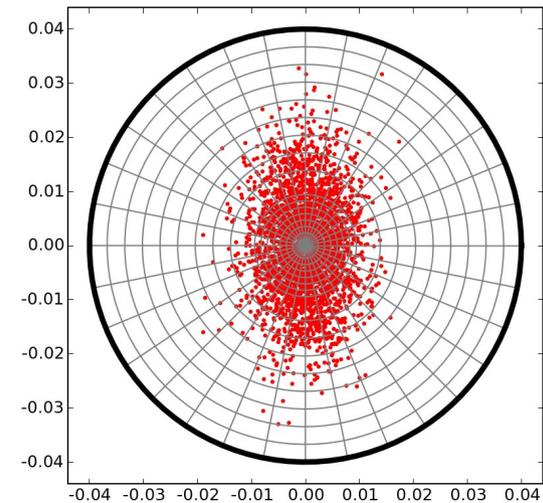
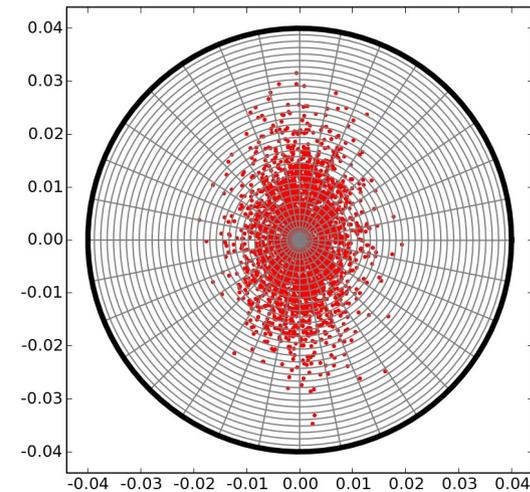


New Poisson solver

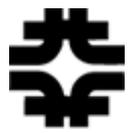
- Default solver: FFT
- Prototype finite difference solver (using state-of-the-art PETSc libraries)
- Implement multi-scale numerical grid
 - Essential for accurate modeling of high aspect ratio beams

Activity at 0.3 FTE level

Uniform grid inefficient,
many empty cells

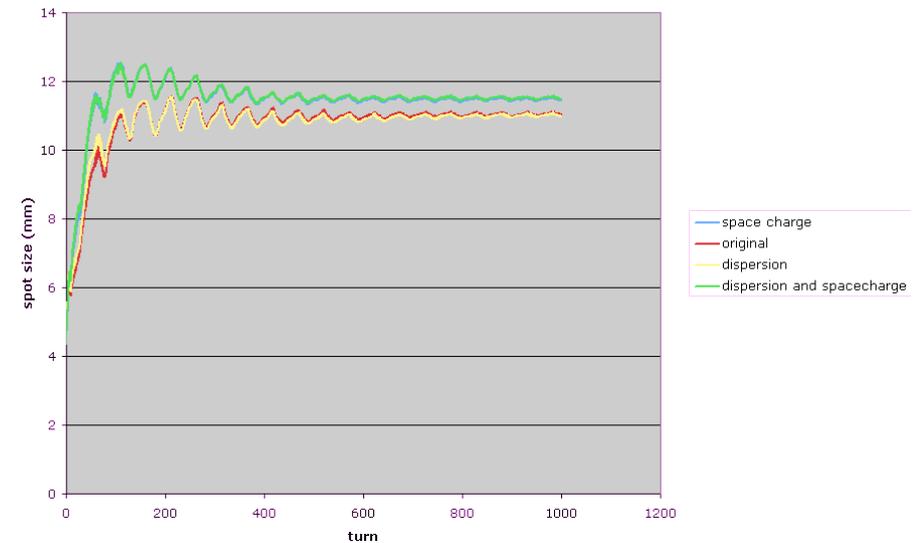
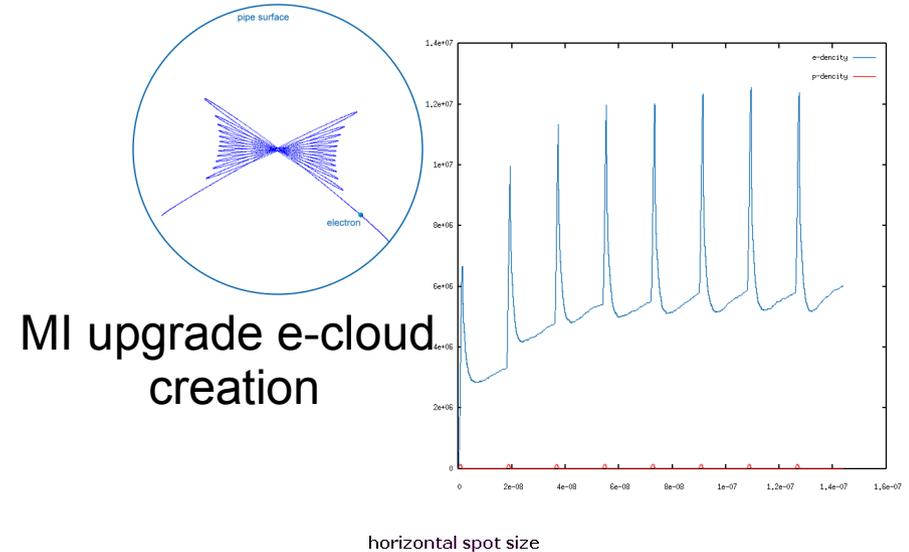


Multi-scale grid achieves same accuracy
with fewer cells



Electron cloud simulations

- Develop Synergia module based on txphysics
 - Begun studying cloud generation for MI upgrade
- Begun studies of e-cloud effects in beam dynamics using QuickPIC (SciDAC, working with USC)
- Activity level @ 0.5FTE (leveraging SciDAC resources)



QuickPIC e-cloud modelling in the MI, for p-driver upgrade ($3E11$ ppb)

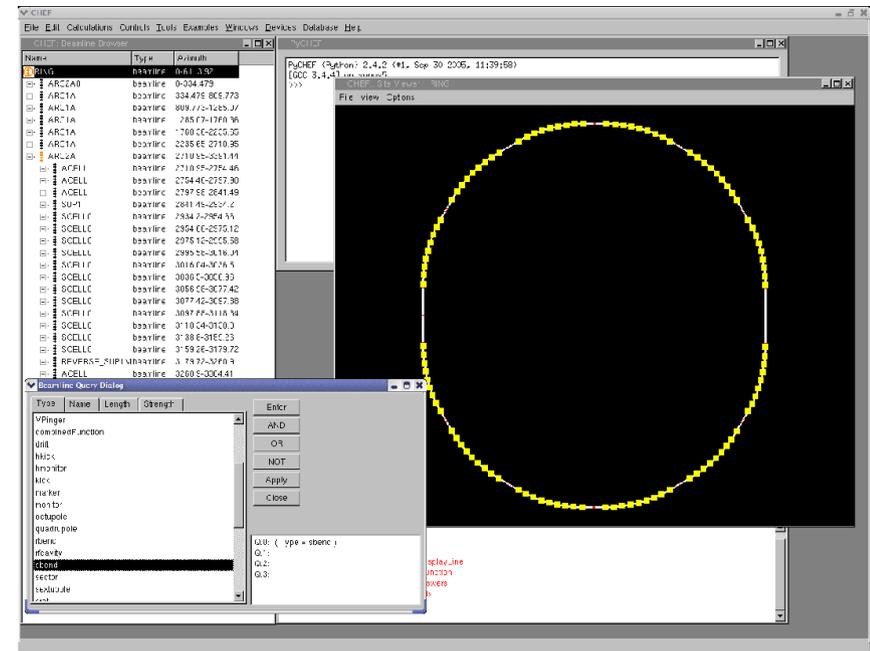


ILC Damping Ring

- Study space-charge effects (halo creation, dynamic aperture) using Synergia (3D, self-consistent).

- Begun lattice studies (CHEF)
- Develop CSR module for CHEF
- Expand cluster for DR dedicated studies (20 nodes)

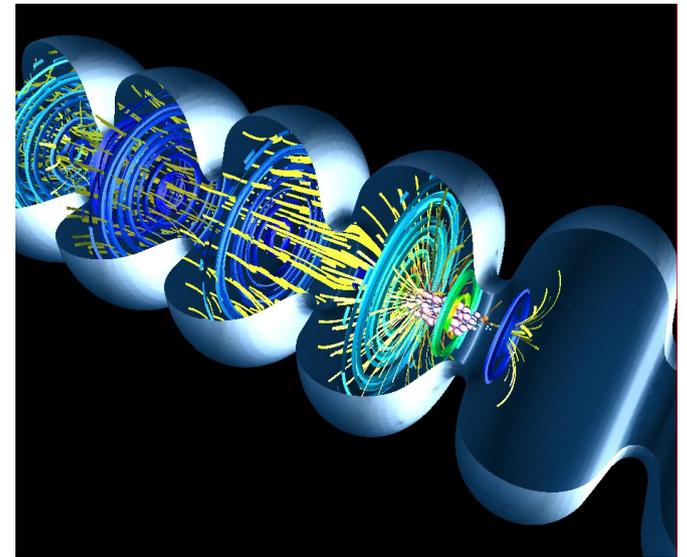
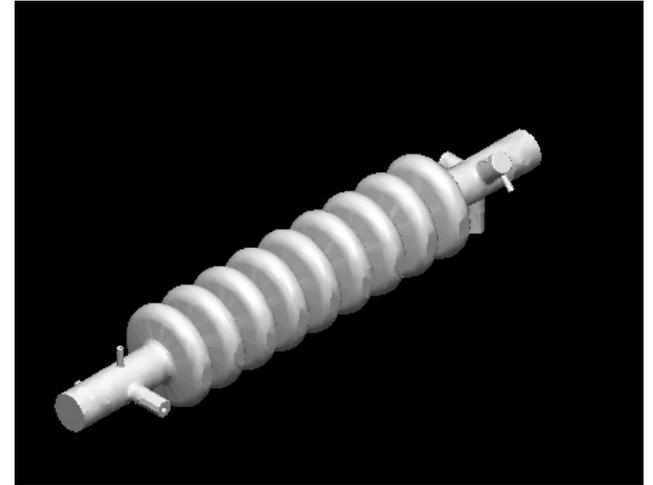
G.I. CHEF & DR lattice





Electromagnetics

- Access to state-of-the-art codes through SciDAC
 - Develop local expertise (newly hired gust scientist)
 - Provide simulation support to ILC crab cavity design
- If SciDAC-2 proposal successful, expand wakefield calculations to ML and DR
 - Use in beam dynamics model
 - Design support(if SciDAC2)
 - **HIGHLY LEVERAGED!**



Longitudinal wakefields in a Tesla cavity from VORPAL



Outlook

- Synergia2 development to support multi-physics simulations
- More emphasis on multi-physics simulations
 - Space-charge & impedance (Booster) & CSR (ILC DR)
 - Beam-beam & impedance (Tevatron)
 - E-cloud generation & dynamics & space-charge (ILC DR, MI)
- Wakefield calculation
 - For beam dynamics & design
- Develop & apply generalized steering package for ILC studies

Requires SciDAC2



Personnel and their expertise

Activity	characteristics	code	CD/AMR expert
1. Single Particle Dynamics			
1. Optics	(Lie methods.	*CHEF	Michelotti)
2. Beam steering, tracking	(MERLIN,	*CHEF, MatLIAR	Lebrun, Michelotti)
2. Multi Particle Dynamics			
1. Space-charge	(3D, parallel.	+Synergia	Spentzouris, Amundson)
2. Beam-beam	(3D, multi-bunch, parallel.	BeamBeam3D	Stern)
3. e-cloud generation	(parallel).	Synergia/txphysics	Spentzouris)
4. e-cloud dynamics	(parallel, quasi-static PIC.	QuicPIC	Spentzouris, Stern)
3. Electromagnetics Modeling	(parallel, time domain.	VORPAL	Ivanov)
4. Generalized Framework			
1. multi-physics interfaces.	(+Synergia		Dechow {SBIR funded}, Amundson)
2. parallel solvers	(+Synergia		Amundson, Dechow).
5. Infrastructure support	(all:		Garren).

*Fermilab developed code

+SciDAC collaboration code with Fermilab lead-developers

SciDAC collaboration code

ILC code